

**UNITED STATES PATENT APPLICATION**

**WIRE-BOND PROCESS FLOW FOR COPPER METAL-SIX,  
STRUCTURES ACHIEVED THEREBY, AND TESTING METHOD**

**INVENTORS**

**Krishna Seshan**

**Kuljeet Singh**

Schwegman, Lundberg, Woessner & Kluth, P.A.  
1600 TCF Tower  
121 South Eighth Street  
Minneapolis, MN 55402  
ATTORNEY DOCKET SLWK 884.659US1  
Client Ref. No. P13236

2010-06-01 10:05:20

# WIRE-BOND PROCESS FLOW FOR COPPER METAL-SIX, STRUCTURES ACHIEVED THEREBY, AND TESTING METHOD

## FIELD OF THE INVENTION

5           The present invention relates generally to electrical testing (e-test) and wire bonding for a metallization process flow. More particularly, the present invention relates to an electroless plating process flow that follows e-test, and for a wire bonding process flow that follows a metal-

6802500T

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25

26

27

28

29

30

31

32

33

34

35

36

37

38

39

40

41

42

43

44

45

46

47

48

49

50

51

52

53

54

55

56

57

58

59

60

61

62

63

64

65

66

67

68

69

70

71

72

73

74

75

76

77

78

79

80

81

82

83

84

85

86

87

88

89

90

91

92

93

94

95

96

97

98

99

100

101

102

103

104

105

106

107

108

109

110

111

112

113

114

115

116

117

118

119

120

121

122

123

124

125

126

127

128

129

130

131

132

133

134

135

136

137

138

139

140

141

142

143

144

145

146

147

148

149

150

151

152

153

154

155

156

157

158

159

160

161

162

163

164

165

166

167

168

169

170

171

172

173

174

175

176

177

178

179

180

181

182

183

184

185

186

187

188

189

190

191

192

193

194

195

196

197

198

199

200

201

202

203

204

205

206

207

208

209

210

211

212

213

214

215

216

217

218

219

220

221

222

223

224

225

226

227

228

229

230

231

232

233

234

235

236

237

238

239

240

241

242

243

244

245

246

247

248

249

250

251

252

253

254

255

256

257

258

259

260

261

262

263

264

265

266

267

268

269

270

271

272

273

274

275

276

277

278

279

280

281

282

283

284

285

286

287

288

289

290

291

292

293

294

295

296

297

298

299

300

301

302

303

304

305

306

307

308

309

310

311

312

313

314

315

316

317

318

319

320

321

322

323

324

325

326

327

328

329

330

331

332

333

334

335

336

337

338

339

340

341

342

343

344

345

346

347

348

349

350

351

352

353

354

355

356

357

358

359

360

361

362

363

364

365

366

367

368

369

370

371

372

373

374

375

376

377

378

379

380

381

382

383

384

385

386

387

388

389

390

391

392

393

394

395

396

397

398

399

400

401

402

403

404

405

406

407

408

409

410

411

412

413

414

415

416

417

418

419

420

421

422

423

424

425

426

427

428

429

430

431

432

433

434

435

436

437

438

439

440

441

442

443

444

445

446

447

448

449

450

451

452

453

454

455

456

457

458

459

460

461

462

463

464

465

466

467

468

469

470

471

472

473

474

475

476

477

478

479

480

481

482

483

484

485

486

487

488

489

490

491

492

493

494

495

496

497

498

499

500

501

502

503

504

505

506

507

508

509

510

511

512

513

514

515

516

517

518

519

520

521

522

523

524

525

526

527

528

529

530

531

532

533

534

535

536

537

538

539

540

541

542

543

544

545

546

547

548

549

550

551

552

553

554

555

556

557

558

559

560

561

562

563

564

565

566

567

568

569

570

571

572

573

574

575

576

577

578

579

580

581

582

583

584

585

586

587

588

589

590

591

592

593

594

595

596

597

598

599

600

601

602

603

604

605

606

607

608

609

610

611

612

613

614

615

616

617

618

619

620

621

622

623

624

625

626

627

628

629

630

631

632

633

634

635

636

637

638

639

640

641

642

643

644

645

646

647

648

649

650

651

652

653

654

655

656

657

658

659

660

661

662

663

664

665

666

667

668

669

670

671

672

673

674

675

676

677

678

679

680

681

682

683

684

685

686

687

688

689

690

691

692

693

694

695

696

697

698

699

700

701

702

703

704

705

706

707

708

709

710

711

712

713

714

715

716

717

718

719

720

721

722

723

724

725

726

727

728

729

730

731

732

733

734

735

736

737

738

739

740

741

742

743

744

745

746

747

748

749

750

751

752

753

754

755

756

757

758

759

760

761

762

763

764

765

766

767

768

769

770

771

772

773

774

775

776

777

778

779

780

781

782

783

784

785

786

787

788

789

790

791

792

793

794

795

796

797

798

799

800

801

802

803

804

805

806

807

808

809

810

811

812

813

814

815

816

817

818

819

820

821

822

823

824

825

826

827

828

829

830

831

832

833

834

835

836

837

838

839

840

841

842

843

844

845

846

847

848

849

850

851

852

853

854

855

856

857

858

859

860

861

862

863

864

865

866

867

868

869

870

871

872

873

874

875

876

877

878

879

880

881

882

883

884

885

886

887

888

889

890

891

892

893

894

895

896

897

898

899

900

901

902

903

904

905

906

907

908

909

910

911

912

913

914

915

916

917

918

919

920

921

922

923

924

925

926

927

928

929

930

931

932

933

934

935

936

937

938

939

940

941

942

943

944

945

946

947

948

949

950

951

952

953

954

955

956

957

958

959

960

961

962

963

964

965

966

967

968

969

970

971

972

973

974

975

976

977

978

979

980

981

982

983

984

985

986

987

988

989

990

991

992

993

994

995

996

997

998

999

1000

1001

1002

1003

1004

1005

1006

1007

1008

1009

1010

1011

1012

1013

1014

1015

1016

1017

1018

1019

1020

1021

1022

1023

1024

1025

1026

1027

1028

1029

1030

1031

1032

1033

1034

1035

1036

1037

1038

1039

1040

1041

1042

1043

1044

1045

1046

1047

1048

1049

1050

1051

1052

1053

1054

1055

1056

1057

1058

1059

1060

1061

1062

1063

1064

1065

1066

1067

1068

1069

1070

1071

1072

1073

1074

1075

1076

1077

1078

1079

1080

1081

1082

1083

1084

1085

1086

1087

1088

1089

1090

1091

1092

1093

1094

1095

1096

1097

1098

1099

1100

1101

1102

1103

1104

1105

1106

1107

1108

1109

1110

1111

1112

1113

1114

1115

1116

1117

1118

1119

1120

1121

1122

1123

1124

1125

1126

1127

1128

1129

1130

1131

1132

1133

1134

1135

1136

1137

1138

1139

1140

1141

1142

1143

1144

1145

1146

1147

1148

1149

1150

1151

1152

1153

1154

1155

1156

1157

1158

1159

1160

1161

1162

1163

1164

1165

1166

1167

1168

1169

1170

1171

1172

1173

1174

1175

1176

1177

1178

1179

1180

1181

1182

1183

1184

1185

1186

1187

1188

1189

1190

1191

1192

1193

1194

1195

1196

1197

1198

1199

1200

1201

1202

1203

1204

1205

1206

1207

1208

1209

1210

1211

1212

1213

1214

1215

1216

1217

1218

1219

1220

1221

1222

1223

1224

1225

1226

1227

1228

1229

1230

1231

1232

1233

1234

1235

1236

1237

1238

1239

1240

1241

1242

1243

1244

1245

1246

1247

1248

1249

1250

1251

1252

1253

1254

1255

1256

1257

1258

1259

1260

1261

1262

1263

1264

1265

1266

1267

1268

1269

1270

1271

1272

1273

1274

1275

1276

1277

1278

1279

1280

1281

1282

1283

1284

1285

1286

1287

1288

1289

1290

1291

1292

1293

1294

1295

1296

1297

1298

1299

1300

1301

1302

1303

1304

1305

1306

1307

1308

1309

1310

1311

1312

1313

1314

1315

1316

1317

1318

1319

1320

1321

1322

1323

1324

1325

1326

1327

1328

1329

1330

1331

1332

1333

1334

1335

1336

1337

1338

1339

1340

1341

1342

1343

1344

1345

1346

1347

1348

1349

1350

1351

1352

1353

1354

1355

1356

1357

1358

1359

1360

1361

1362

1363

1364

1365

1366

1367

1368

1369

1370

1371

1372

1373

1374

1375

1376

1377

1378

1379

1380

1381

1382

1383

1384

1385

1386

1387

1388

1389

1390

1391

1392

1393

1394

1395

1396

1397

1398

1399

1400

1401

1402

1403

1404

1405

1406

1407

1408

1409

1410

1411

1412

1413

1414

1415

1416

1417

1418

1419

1420

1421

1422

1423

1424

1425

1426

1427

1428

1429

1430

1431

1432

1433

1434

1435

1436

1437

1438

1439

1440

1441

1442

1443

1444

1445

1446

1447

1448

1449

1450

1451

1452

1453

1454

1455

1456

1457

1458

1459

1460

1461

1462

1463

1464

1465

1466

1467

1468

1469

1470

1471

1472

1473

1474

1475

1476

1477

1478

1479

test (HAST) and/or burn-in, add to corrosion 22. Other processing conditions add to corrosion including the galvanic differential that is established between the two disparate metals of upper metallization 14 and wire bond 20. Once corrosion begins, a variable and unpredictable contact resistance (CRES) occurs between the numerous probes and the upper metallization 14.

5 Additionally, a copper scumming of the probe tip requires frequent and unpredictable cleaning.

#### BRIEF DESCRIPTION OF THE DRAWINGS

In order to illustrate the manner in which embodiments of the invention are obtained, a more particular description of the invention briefly described above will be rendered by reference to specific embodiments thereof which are illustrated in the appended drawings.

10 Understanding that these drawings depict only typical embodiments of the invention that are not necessarily drawn to scale and are not therefore to be considered to be limiting of its scope, the invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

**Figure 1** is a cross-section of a semiconductor structure during processing  
15 according to an embodiment;

**Figure 2** is a cross-section of the semiconductor structure depicted in Figure 1 after further processing;

**Figure 3** is a cross-section of the semiconductor structure depicted in Figure 2 after further processing;

20 **Figure 4** is a cross-section of the semiconductor structure depicted in Figure 3 after further processing;

**Figure 5** is a cross-section of the semiconductor structure depicted in Figure 4 after further processing, and that also illustrates an e-test embodiment;

**Figure 6** is a cross-section of the semiconductor structure depicted in **Figure 4**, after further processing, and that also illustrates a wire-bond embodiment;

**Figure 7** illustrates a process flow according to an embodiment; and

**Figure 8** is a cross-section of a known semiconductor structure.

5

## DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to a wire-bond process flow that minimizes copper corrosion in the copper pad or other metallization that is wire bonded. In one embodiment, a structure embodiment is disclosed that resists corrosion of the copper pad or other metallization during processing, testing, and field use. In another embodiment, the structure embodiment is used in an electrical testing (e-test) during wafer sorting, that does not damage the copper pad or the like, and that minimizes e-test error but also lowers the e-test resistance. In one embodiment, an e-test method is disclosed that uses the inventive structure embodiment.

According to an embodiment, **Figure 1** is a cross-section of a semiconductor structure 110 during fabrication that includes a substrate 112 and metallization 114 such as copper pads that make connection to what is commonly referred to as metal-six copper (M6 Cu) by way of non-limiting example. Metallization 114 may be disposed with an upper surface 116 that is coplanar with substrate 112 where substrate 112 may be an interlayer dielectric (ILD) composition. A nitride layer 118 and a passivation layer 120 are formed over substrate 112 and metallization 114. It is noted that metallization 114 is connected through a contact 122 to a lower metallization 124.

Nitride layer 118 and passivation layer 120 act to protect substrate 112 and to expose a portion of metallization 114 according to subsequent patterning. Passivation layer 120 may be a

polyimide material or it may be an inorganic material such as a silicon oxide that is formed by the decomposition of tetraethyl ortho silicate (TEOS). Patterning is accomplished by a mask (not pictured) that exposes passivation layer 120.

**Figure 2** illustrates a patterned passivation structure, that includes portions of nitride layer 118 and passivation layer 120, and that exposes a portion of metallization 114. The process may be carried out by blanket forming nitride layer 118 and passivation layer 120, patterning, etching a recess 126, and curing passivation layer 120 where passivation layer 120 is a polyimide or the like. In one embodiment after the cure, passivation layer 120 has formed a slope that has an angle 128, in a range from about 30° to about 60°. In one embodiment after the cure, passivation layer 120 has formed angle 128 that is about 45°.

**Figure 3** illustrates further processing according to embodiments. A protective structure is formed that protects metallization 114 during testing, but that also allows for a lower-resistance test method. In a first process flow, a protective structure is made that includes a metal first film 130 that is disposed above and on the metallization 114. Metal first film 130 acts as a penetration barrier that may otherwise prevent damage by a test probe tip during e-test according to an embodiment. The thickness of metal first film 130 is in a range from about 1,000Å to about 1,500 Å. In another embodiment, the thickness of metal first film 130 is about 500 Å.

In one embodiment, metal first film 130 is a refractory (hard) metal or alloy, and metallization 114 is a M6 Cu pad. Metal first film 130 is formed by a deposition process flow that is selected from vapor deposition, electroplating, and electroless plating. The vapor deposition is selected from chemical vapor deposition (CVD), including modified CVD such as plasma-enhanced CVD (PECVD), and atomic layer CVD (ALCVD). In another embodiment,

physical vapor deposition (PVD) is used for form metal first film 130. The conditions of PVD may be selected in order to achieve a desired morphology of metal first film 130. In the vapor depositing embodiments, after a blanket deposition, a center-patterned masking (not pictured) is carried out that blinds metal first film 130. Thereafter, an etch is used to strip off unwanted refractory metal material. The etch is a wet etch or a dry etch according to a selected process integration plan.

Refractory metals for metal first film 130 include nickel (Ni), palladium (Pd), platinum (Pt), and the like. In another embodiment, refractory metals for metal first film 130 include cobalt (Co), rhodium (Rh), iridium (Ir), and the like. In another embodiment, refractory metals for metal first film 130 include scandium (Sc), yttrium (Yt), lanthanum (La), cerium (Ce), and the like. One property embodiment is that metal first film 130 exhibits sufficient adhesion to the metallization that liftoff or spalling thereof will not occur during fabrication, test, and ordinary field use. In another embodiment, metal first film 130 is selected from nickel, palladium, cobalt, tungsten, chromium, titanium, ti-tungsten (TiW), zirconium, hafnium, and the like. Another property embodiment is that metal first film 130 is hard enough that an ordinary tungsten test probe or the like, will not penetrate metal first film 130 during ordinary e-test conditions.

Besides vapor depositing, liquid plating processing may be done. Such liquid plating processing embodiments include spray deposition, electroplating and electroless plating. One advantage of electroless plating of the metal first film 130, is that due to the chemically-induced oxidation-reduction reaction that is carried out only at chemically enabled sites, no post-deposition patterning and etching needs to be done. According to an embodiment, semiconductor structure 110 is immersed in a bath that contains one or more metal ions, and

reduction of the ions occurs at the exposed portion of metallization 114 to form metal first film 130.

As set forth herein, metal first film 130 is preferably a refractory metal. In conjunction with a second metal film 132 (see Figure 4) and according to an embodiment, metal first film 130 is less noble than the second metal film 132 (Figure 4). The metal ion or ions that are used to form metal first film 130 may be selected from various metals or combinations thereof. In one embodiment, the metal is selected from at least one primary metal and from zero to at least one secondary metal. The at least one primary metal is selected from the group of nickel (Ni), palladium (Pd), platinum (Pt), and combinations thereof. In one embodiment, the at least one primary metal is selected from the group of cobalt (Co), rhodium (Rh), iridium (Ir), and combinations thereof. In one embodiment, the at least one primary metal is selected from the group of copper (Cu), silver (Ag), gold (Au), and combinations thereof. In another embodiment, the at least one primary metal is selected from a combination of at least two metals that combine metals from the above-referenced groups. In one embodiment, the primary metal(s) is supplied in a concentration range from about 2 gram/liter to about 50 gram/liter. In another embodiment, the primary metal(s) is supplied in a concentration range from about 5 gram/liter to about 35 gram/liter.

In one embodiment, at least one secondary metal is added to the primary metal(s) to form metal first film 130. In one embodiment, the at least one secondary metal is selected from the group of chromium (Cr), molybdenum (Mo), tungsten (W), and combinations thereof. In another embodiment, the at least one secondary metal is selected from the group of manganese (Mn), technetium (Tc), rhenium (Re), and combinations thereof. In another embodiment, the at least one secondary metal is selected from a combination of at least two metals that combine

metals from the above-referenced groups. In one embodiment, the secondary metal(s) is supplied in a concentration range from about 1 gram/liter to about 40 gram/liter. In another embodiment, the secondary metal(s) is supplied in a concentration range from about 2 gram/liter to about 35 gram/liter.

5 Reducing agents are provided to assist in assuring metal deposition if metal first film 130, as the chemical environment of the substrate onto which the metal deposits continues to change. Although initial deposition of a metal ion onto a substrate may be autocatalytic, the changing chemical environment may interrupt the autocatalytic environment. In one embodiment, where deposition is upon a Cu M6 metallization pad 114 as known in the art, initial deposition will be  
10 achieved in the presence of the Cu M6 pad 114. Consequently, the Cu M6 pad 114 affects the initial, presumably oxidation-reduction (REDOX) deposition chemistry. However, as the Cu M6 pad 114 is covered by way of non-limiting example, by nickel, the REDOX chemical environment changes from a nickel-onto-copper plating, to a nickel-onto-nickel plating. Accordingly, a reducing agent(s) is provided to assure continued nickel plating despite the  
15 changed substrate environment.

In one embodiment, the electroless plating composition is combined with from zero to at least one primary reducing agent in a mixture of solvents. In one embodiment, a primary reducing agent including boron (B) is provided. Primary reducing agents that can be utilized for this application include ammonium, alkali metal, alkaline earth metal borohydrides, and the like,  
20 and combinations thereof. In one embodiment, inorganic primary reducing agent embodiments include sodium borohydride, lithium borohydride, zinc borohydride, and the like, and combinations thereof. In one embodiment, an organic primary reducing agent is dimethylaminoborane (DMAB). In another embodiment, other aminoboranes are used such as



diethylaminoborane, morpholine borane, combinations thereof, and the like. In one embodiment, the primary reducing agent(s) is supplied in a concentration range from about 1 gram/liter to about 30 gram/liter. In another embodiment, the primary reducing agent(s) is supplied in a concentration range from about 2 gram/liter to about 20 gram/liter.

5 In one embodiment, a secondary reducing agent is provided to assist the changing chemical environment during deposition of the primary metal and optional secondary metal. However, the secondary reducing agent may be used alone, without the primary reducing agent. In one embodiment a phosphorus-containing compound is selected as the secondary reducing agent. Phosphorus-containing compounds may include hypophosphites. In one embodiment, the hypophosphite is selected from organic hypophosphites such as ammonium hypophosphite and the like.

10 In one embodiment, the hypophosphite is selected from inorganic hypophosphites such as sodium hypophosphite and the like. One embodiment includes an inorganic phosphorus-containing compound such as hypophosphites of lithium, sodium, potassium, and mixtures thereof. One embodiment includes an inorganic phosphorus-containing compound such as hypophosphites of, magnesium, calcium, strontium, and mixtures thereof. One embodiment includes an inorganic phosphorus-containing compound such as nickel hypophosphite and the like. One embodiment includes an inorganic phosphorus-containing compound such as hypophosphorous acid and the like.

20 Other secondary reducing agents are selected from sulfites, bisulfites, hydrosulfites, metabisulfites, and the like. Other secondary reducing agents are selected from dithionates, and tetrathionates, and the like. Other secondary reducing agents are selected from thiosulfates, thioureas, and the like. Other secondary reducing agents are selected from hydrazines,

hydroxylamines, aldehydes, glyoxylic acid, and reducing sugars. In another embodiment, the secondary reducing agent is selected from diisobutylaluminum hydride, sodium bis(2-methoxyethoxy)aluminum hydride, and the like.

5 In one embodiment, the secondary reducing agent(s) is supplied in a concentration range from about 0 gram/liter to about 5 gram/liter. In another embodiment, the secondary reducing agent(s) is supplied in a concentration range from about 1 gram/liter to about 2 gram/liter.

10 In one embodiment, the primary reducing agent is DMAB in a concentration range from about 1 gram/liter to about 30 gram/liter, and the secondary reducing agent is ammonium hypophosphite in a concentration range from about 0 gram/liter to about 2 gram/liter. Other embodiments include primary and secondary reducing agents that are substituted for DMAB and ammonium hypophosphite, or one of them, as long as they approximate the gram equivalent amounts of the primary and secondary reducing agents of the DMAB and the ammonium hypophosphite. The gram equivalent amounts may be adjusted by various means, such as according to the comparative dissociation constants of the reducing agents.

15 In addition to the reducing agents, other agents may be added such alkaline metal-free chelating agents. Embodiments of chelating agents include citric acid, ammonium chloride, glycine, acetic acid, malonic acid, and the like in concentration range from about 5 gram/liter to about 70 gram/liter.

20 A complexing agent and a buffering agent are also used to hold the metal ion(s) in solution until deposition is appropriate. In one embodiment, an organic sulfate salt compound is used such as ammonium sulfate,  $(\text{NH})_2\text{SO}_4$  and the like. Other complexing and buffering agents may be selected that have an effective gram equivalent amount to the  $(\text{NH})_2\text{SO}_4$  such as copper sulfate,  $\text{CuSO}_4$ . In one embodiment, the complexing/buffering agent is supplied in a

concentration range from about 50 gram/liter to about 1,000 gram/liter. In another embodiment, the complexing/buffering agent is supplied in a concentration range from about 80 gram/liter to about 600 gram/liter.

Various pH-adjusting compositions may be used including organic and inorganic bases.

- 5 That a compound is basic can be easily confirmed by dipping pH test paper, measuring its aqueous solution using a pH meter, observing the discoloration caused by an indicator or measuring the adsorption of carbonic acid gas, and by other methods.

- 10 In one embodiment, the organic base compounds which can be used include organic amines such as pyridine, pyrrolidine, combinations thereof, and the like. Other embodiments include methylamine, dimethylamine, trimethylamine, combinations thereof, and the like. Other embodiments include ethylamine, diethylamine, triethylamine, combinations thereof, and the like. Other embodiments include tetramethylammonium hydroxide (TMAH), tetraethyl ammonium hydroxide (TEAH), tetrapropyl ammonium hydroxide (TPAH), tetrabutyl ammonium hydroxide (TBAH), combinations thereof, and the like. Other embodiments include  
15 aniline, toluidine, and the like.

In one embodiment, the organic base includes TMAH in a concentration range from about 30 mL to about 150 mL, added to a 100 mL volume of the other constituents of the inventive electroless plating solution. Other embodiments include the gram equivalent amounts of the organic base compounds set forth herein.

- 20 In one embodiment, the inorganic base compounds which can be used are salts of strong bases and weak acids. In one embodiment, alkali metal acetates, alkaline earth metal acetates, and combinations thereof are used. In one embodiment, alkali metal propionates, alkaline earth metal propionates, and combinations thereof are used. In one embodiment, alkali metal

carbonates, alkaline earth metal carbonates, and combinations thereof are used. In one embodiment, alkali metal hydroxides, alkaline earth metal hydroxides, and combinations thereof are used. In one embodiment, combinations of at least two of the acetates, propionates, carbonates, and hydroxides is used.

5 Inorganic base compounds may be provided in a concentration such as a 25% sodium hydroxide, NaOH in a deionized (DI) water solution, to make a volume of about 10 mL to about 50 mL. This volume of solution is added to an about 100 mL volume of the other inventive electroless plating composition constituents. Other embodiments include the gram equivalent amounts of the inorganic base compounds set forth herein.

10 Other compounds may be added to the inventive electroless plating composition such as surface active agents. One commercial surfactant is RHODAFAC RE 610, made by Aventis (formerly Rhone-Poulenc Hoechst). Another commercial surfactant is Triton x-100T<sup>TM</sup> made by Sigma-Aldrich. Other surfactants include cystine, polyethylene glycols, polypropylene glycol (PPG)/polyethylene glycol (PEG) (in a molecular range of approximately 200 to 10,000) in a  
15 concentration range of about 0.01 to 5 gram/liter, and the like.

Several combinations of primary and secondary metals are achievable according to various embodiments. The primary metal may include, but is not limited to from zero to at least one metal, selected from nickel, palladium, platinum, cobalt, rhodium, iridium, copper, silver, and gold and combinations thereof, although other refractory metals may be selected as set forth  
20 herein. The secondary metal may include, but is not limited to from zero to at least one metal selected from chromium, molybdenum, tungsten, manganese, technetium, and rhenium. In one embodiment, because of the presence of at least one of the primary and secondary reducing agents, a metallic compound forms that incorporates at least one of boron and phosphorus.

20970689-014502

In one embodiment, nickel is a primary metal for an electroless plating embodiment to form metal first film 130, the composition includes a nickel solution to form a nickel plating layer. According to an embodiment, where nickel is the primary metal, because of the inventive electroless plating bath environment, a metallic film forms that includes but is not limited by such combinations as NiB, NiP, NiBP, NiCrB, NiCrP, NiCrBP, NiMoB, NiMoP, NiMoBP, NiWB, NiWP, NiWBP, NiMnB, NiMnP, NiMnBP, NiTcB, NiTcP, NiTcBP, NiReB, NiReP, and NiReBP. In these nickel compounds, as in other embodiments set forth in this disclosure, where a given element is listed first, second, third, etc., one embodiment includes the largest presence in the first-listed element, the second largest presence in the second listed element, etc. Thus, where NiCrB is set forth, the concentrations may be 70Ni28Cr2B, by way of non-limiting example. Where two primary metals are used in solution, the inventive electroless plating bath environment may form metal first film 130 that includes but is not limited by such combinations as to NiCoB, NiCoP, NiCoBP, NiCoCrB, NiCoCrP, NiCoCrBP, NiCoMoB, NiCoMoP, NiCoMoBP, NiCoWB, NiCoWP, NiCoWBP, NiCoMnB, NiCoMnP, NiCoMnBP, NiCoTcB, NiCoTcP, NiCoTcBP, NiCoReB, NiCoReP, and NiCoReBP. It can be seen that at least zero- to at least one primary metals and from zero to at least one secondary metals are combinable according to various embodiments. In similar embodiments, palladium can be used in place of- or in addition to nickel. Similarly, platinum can be used in place of- or in addition to nickel. Additionally, a blend of at least two of nickel, palladium, and platinum can be used as set forth herein.

In another embodiment, metal first film 130 uses cobalt is a primary metal for an electroless plating embodiment, the composition includes a cobalt solution to form a cobalt plating layer. According to an embodiment, where cobalt is the primary metal, because of the

inventive electroless plating bath environment, metallic films form that include but are not limited by such combinations as CoB, CoP, CoBP, CoCrB, CoCrP, CoCrBP, CoMoB, CoMoP, CoMoBP, CoWB, CoWP, CoWBP, CoMnB, CoMnP, CoMnBP, CoTcB, CoTcP, CoTcBP, CoReB, CoReP, and CoReBP. Where two primary metals are used in solution, the inventive electroless plating bath environment may form metallic films that include but not are limited by such combinations as to CoNiB, CoNiP, CoPdBP, CoPdCrB, CoPdCrP, CoPdCrBP, CoPdMoB, CoPdMoP, CoPdMoBP, CoPdWB, CoPdWP, CoPdWBP, CoPdMnB, CoPdMnP, CoPdMnBP, CoPdTcB, CoPdTcP, CoPdTcBP, CoPdReB, CoPdReP, and CoPdReBP.

It can be seen that zero to at least one primary metal and from zero to at least one secondary metal are combinable according to various embodiments to form metal first film 130. In similar embodiments, rhodium can be used in place of, or in addition to cobalt. Similarly, iridium can be used in place of, or in addition to cobalt. Additionally, a blend of at least two of cobalt, rhodium, and iridium can be used as set forth herein.

By way of non-limiting example, copper is used to form metal first film 130 as a primary metal for an electroless plating embodiment. The composition includes a copper solution to form a copper plating layer. According to an embodiment, where copper is the primary metal, because of the inventive electroless plating bath environment, metallic films form that include but are not limited by such combinations as CuB, CuP, CuBP, CuCrB, CuCrP, CuCrBP, CuMoB, CuMoP, CuMoBP, CuWB, CuWP, CuWBP, CuMnB, CuMnP, CuMnBP, CuTcB, CuTcP, CuTcBP, CuReB, CuReP, and CuReBP. Where two primary metals are used in solution, the inventive electroless plating bath environment may form metallic films that include but not are limited by such combinations as to CuNiB, CuNiP, CuNiBP, CuNiCrB, CuNiCrP, CuNiCrBP, CuNiMoB, CuNiMoP, CuNiMoBP, CuNiWB, CuNiWP, CuNiWBP, CuNiMnB,

CuNiMnP, CuNiMnBP, CuNiTcB, CuNiTcP, CuNiTcBP, CuNiReB, CuNiReP, and CuNiReBP.

It can be seen that from zero to at least one primary metal and from zero to at least one secondary metal is combinable according to various embodiments. In similar embodiments, silver can be used in place of, or in addition to copper. Similarly, gold or silver can be used in place of- or in addition to copper. Additionally, a blend of at least two of copper, silver, and gold can be used as set forth herein.

**Figure 4** illustrates further processing after the formation of metal first film 130. A metal second film 132 is formed that in one embodiment is at least one of a more noble, or a softer (more ductile) metal than metal first film 130. In one embodiment, metal second film 132 is selected from gold, doré, platinum, and the like. In another embodiment, metal second film 132 is aluminum, and metal first film 130 is selected from titanium, tungsten, ti-tungsten, zirconium, hafnium, and other refractory metals and refractory metal alloys as set forth herein.

One embodiment includes a metal second film 132 that resists alloying with a bond wire (see Figure 6) during ordinary wire-bonding process flows. Typically, an aluminum bond wire is attached to metal second film 132. In such embodiments, metal second film 132 is of a composition that is substantially immiscible with aluminum under ordinary wire-bonding conditions.

The formation of metal second film 132 is carried out according to vapor or liquid plating techniques as set forth herein. In one embodiment, metal second film 132 is carried out by electroless plating by using a gold-cyanide electroless plating solution, and the Merrill-Crowe technique. In this embodiment, an atom-thick layer of zinc (Zn, not pictured) is pre-plated onto metal first film 130 by an electroless process that does not substantially cover passivation layer

120, and the gold-cyanide solution is contacted with the zinc which causes the reduction of the gold out of the gold-cyanide complex.

In another electroless plating embodiment, semiconductor structure 110 is contacted with a gold halide solution, and the Eh-pH environment of the solution is manipulated according to the technique pioneered by Pourbaix. In one embodiment, metal first film 130 acts as an autocatalytic surface to assist the selective precipitation of the gold of metal second film 132 as depicted in Figure 4.

In another embodiment, a CVD process is carried out during which a organometallic gold vapor or a gold halide vapor is metered toward semiconductor structure 110, blanket deposited, and patterned with an etch. In another embodiment, a PVD process is carried out in which a gold target is impinged under PVD conditions to form a blanket layer of gold that is subsequently patterned into metal second film 132.

In another embodiment, a metal second film 132 is aluminum that is formed on a metal first film 130 of titanium. The formation of metal second film 132 is by CVD or PVD.

In one embodiment, metal first film 130 has a thickness in a range from about 500 Å to about 2,000 Å. In another embodiment, metal first film 130 has a thickness of about 1,000 Å. In one embodiment, metal second film 132 has a thickness in a range from about 100 nm to about 1,000 nm. In one embodiment, metal second film 132 has a thickness in a range from about 300 nm to about 500 nm. In one embodiment, metal first film 130 is from about 500 Å to about 2,000 Å and metal second film 132 is from about 0.3 microns to about 0.5 microns.

Another embodiment of the present invention relates to an e-test method according to the process embodiments. **Figure 5** illustrates semiconductor structure 110 during an e-test, before wire bonding is carried out (Figure 6). A tungsten test probe tip 134 or the like is depicted as



penetrating into and through metal second film 132, and making contact against metal first film 130 without penetrating it. Tip 134 under prior methods, experienced an ohmic resistance in a range from about 5 ohms ( $\Omega$ ) or greater. According to an embodiment, the ohmic resistance during an e-test is in a range from about 0.5  $\Omega$  to about 4  $\Omega$ . In another embodiment, the ohmic resistance during an e-test is in a range from about 0.75  $\Omega$  to about 2  $\Omega$ . In another embodiment, the ohmic resistance during an e-test is in a range from about 0.95  $\Omega$  to about 1.5  $\Omega$ . In another embodiment, the ohmic resistance during an e-test is about 1  $\Omega$ .

In a first example, a protective structure is formed by plating nickel as a metal first film 130, and gold as a metal second film 132. Patterning is done by a clear field mask to center-pattern metal first film 130 and metal second film 132. Etching is carried out, followed by testing. During the probe test, the ohmic resistance is in a range from about 0.5  $\Omega$  to about 4  $\Omega$ , and the first standard deviation of the ohmic resistance is less than about 2  $\Omega$ .

In a second example, a protective structure was formed by depositing titanium as a metal first film 130, and depositing aluminum as a metal second film 132. Patterning was done by a clear field mask to center-pattern metal first film 130 and metal second film 132. Etching was carried out, followed by testing. During the probe test, the ohmic resistance had a mean value of about 1.5  $\Omega$ , and the first standard deviation of the ohmic resistance was about 0.1  $\Omega$ .

In a comparative example, a tungsten test probe tip was impinged on a copper metallization. The ohmic resistance had a mean value of about 5  $\Omega$ , and the first standard deviation of the ohmic resistance was about 2  $\Omega$ . During this comparative example, a deformation of the copper metallization was observed, as well as a scumming of the tungsten test probe tip with some of the copper.

Under previous process flows, and according to previous architectures, corrosion of the upper metallization would be significant enough to cause the rejection of several devices during the probe for sort e-test. According to an embodiment of the present invention, metal first film 130 protects copper metallization 114 from physical stresses, and metal second film 132 protects copper metallization from corrosive stresses.

**Figure 6** illustrates an embodiment of the semiconductor structure 110 after e-test, or after further processing. A bond wire 136 is depicted as having been bonded to metal second film 132. As set forth herein, the metal of bond wire 136 is selected from aluminum and the like according to known technique. Metal second film 132 is a material that resists alloying with bond wire 136, and preferably is a gold, doré, or platinum material.

One feature of an embodiment is the ability of the metal second film 132 to bond with bond wire 136, but not to alloy therewith. In some applications, a bond wire article may be rejected by pulling or cutting the bond wires and repeating the bond wire process flow. According to an embodiment, because metallization 114 is significantly protected from both physical and corrosive stresses, the bond wire 136 is cut or pulled away from metal second film 132, and wire bonding is repeated with no significant change in the ohmic resistance through metal second film 132 and metal first film 130. Accordingly, ohmic resistance in a second bond wire process when compared to a first bond-wire process changes, by a range from about 50% reduction to about 150% improvement, and in another embodiment, from about 10% reduction to about 110% improvement.

**Figure 7** is a process flow depiction according to an embodiment. The process 700 commences by forming 710 a protective structure above a metallization. In one particular exemplary embodiment, the protective structure includes metal first film 130 and metal second

film 132 as illustrated in Figures 4-6. Further, the metallization is an M6 Cu pad 114. Next, the process of an e-test is depicted by testing 720 the device by probing the metallization with a probe tip. After an e-test, the process continues by wire bonding 730 the device to the protective structure. In one particular exemplary embodiment, the protective structure is the metal second  
5 film 132 that is bonded to the bond wire. Finally, where the rejection of a wire-bonding run is required, the wire bond is pulled and a replacement wire bonding is done 740.

It will be readily understood to those skilled in the art that various other changes in the details, material, and arrangements of the parts and method stages which have been described and illustrated in order to explain the nature of this invention may be made without departing  
10 from the principles and scope of the invention as expressed in the subjoined claims.